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REDUCED COHERENCE SYMMETRIC GRAZING INCIDENCE  
DIFFERENTIAL INTERFEROMETER

BY

Dieter Mueller  
Daniel Ivanov Kavaldjiev  
Rainer Schierle

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REDUCED COHERENCE SYMMETRIC GRAZING INCIDENCE  
DIFFERENTIAL INTERFEROMETER

5        This application is a continuation in part of  
United States Patent Application 09/335,673, entitled  
"Method and Apparatus for Scanning, Stitching, and  
Damping Measurements of a Double-Sided Inspection  
Tool" filed on June 18, 1999, the entirety of which is  
10 hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

15        The present invention relates generally to the  
field of optical imaging and more particularly to  
systems for sub-aperture data imaging of double sided  
interferometric specimens, such as semiconductor  
wafers.

Description of the Related Art

20        The progress of the semiconductor industry over  
the last years has resulted in a sharp increase in the  
diameters of semiconductor wafers as base material for  
chip production for economic and process technical  
reasons. Wafers having diameters of 200 and 300  
25 millimeters are currently processed as a matter of  
course.

At present manufacturers and processors of wafers  
in the 200 and 300 mm range have been unable to

achieve the desired features, namely, uniformity,  
accuracy, and thickness variation, with sufficient  
resolution and precision.

As scanning of specimens has improved to the sub-aperture range, the time required to perform full specimen inspection for a dual-sided specimen has also increased. Various inspection approaches have been employed, such as performing an inspection of one side of the specimen, inverting the specimen, and then inspecting the other side thereof. Such a system requires mechanically handling the specimen, which is undesirable. Further, the act of inspecting the specimen has generally required binding the specimen, which can cause deformation at the edges of the specimen, increase defects at the edge, or cause bending of the specimen during inspection.

One method for inspecting both sides of a dual sided specimen is disclosed in PCT Application PCT/EP/03881 to Dieter Mueller and currently assigned to the KLA-Tencor Corporation, the assignee of the current application. The system disclosed therein uses a phase shifting interferometric design which facilitates the simultaneous topography measurement of both sides of a specimen, such as a semiconductor wafer, as well as the thickness variation of the wafer. A simplified drawing of the Mueller grazing incidence interferometer design is illustrated in FIG. 1A. The system of FIG. 1A uses a collimated laser light source 101 along with a lens arrangement 102 to cause grazing of light energy off the surface of both

surfaces of the specimen and a detector 103 positioned for detection of the light energy.

The design of FIG. 1A is highly useful in performing topographical measurements for both sides of a dual-sided specimen in a single measurement cycle, but suffers from some drawbacks. First, the system requires minimum specimen movement during measurement, which can be difficult due to vibration in the surrounding area and vibration of the specimen itself. Further, the inspection can be time consuming and requires highly precise light energy application and lensing, which is expensive. The specimen must be free standing and free of edge forces, and the incidence geometry during inspection must be unimpeded. Illumination access must be preserved under all incidence angles. These factors provide mechanical challenges for successfully supporting the specimen; excessive application of force at a minimum number of points may deform the specimen, while numerous contact points impede access and require exact positioning to avoid specimen deformation or bending during inspection. Further, edge support of the specimen has a tendency to cause the specimen to act like a membrane and induce vibration due to slight acoustic or seismic disturbances. This membrane tendency combined with the other problems noted above have generally been addressed by including most components of the system within an enclosure that minimizes ambient vibrations, which adds significant

Further, the present system has a tendency to require excessive coherence lengths. As is generally

along the emitted laser beam over which the laser light has sufficient coherence to produce visible interference fringes. Coherence length is important when a laser beam is split and recombined to form an interference pattern, as in the system presented in FIG. 1A.

In general, when a laser beam is split, the optical path difference is the difference in length between the two paths before recombining. If the optical path difference is less than the longitudinal spatial coherence length of the light beam, interference fringes are formed at the receiving element, or screen. If the optical path difference is greater than the longitudinal spatial coherence length, no interference fringes form. Thus it is desirable to have a small spatial coherence length to minimize the size of the components involved.

The system of FIG. 1A provides a high spatial coherence between the reference wave fronts and the specimen wave fronts. Such a system makes the overall measurement system highly sensitive to background noise along the optical path. The noise creates a diffraction pattern on top of the measurement signal and thus degrades the image obtained of the surfaces. In particular, the background signal tends to be unstable and can be difficult to correct using compensation techniques.

FIG. 1A is a schematic diagram of an optical system. The system includes a laser source, a beam splitter, a reference mirror, a specimen, and a detector. The laser source emits a beam that is split by the beam splitter. One part of the beam is reflected by the reference mirror and the other part is reflected by the specimen. The two beams are then recombined and detected by the detector. The system is designed to measure the surface profile of the specimen.

application. Full aperture decollimating optics, including precision lenses, gratings, and beamsplitters used in a configuration for performing full inspection of a 300 millimeter specimen are  
 5 extremely expensive, generally costing orders of magnitude more than optical components half the diameter of the wafer.

Further, the system disclosed in FIG. 1A requires a high spatial coherence between the reference wave  
 10 fronts and the specimen wave fronts, making the system sensitive to background noise along the optical path. Noise creates a diffraction pattern that increases the measurement signal in a random fashion. The result unstable and compensation for the combined effect is  
 15 extremely difficult.

It is an object of the current system to provide a system having a relatively small spatial coherence length to minimize system sensitivity to background noise along the optical path and permit use of  
 20 reasonably sized enclosure components.

It is another object of the current invention to provide a system for performing a single measurement cycle inspection of a dual-sided specimen having dimensions up to and greater than 300 millimeters.

25 It is a further object of the present invention to provide a system for inspection of dual-sided specimens without requiring an excessive number of

It is a further object of the current invention to provide for the single measurement cycle inspection

for the specimen to behave as a membrane and minimize any acoustic and/or seismic vibrations associated with the inspection apparatus and process.

It is still a further object of the present invention to accomplish all of the aforesaid objectives at a relatively low cost, particularly in connection with the collimating and decollimating optics and any enclosures required to minimize acoustic and seismic vibrations.

#### 10 SUMMARY OF THE INVENTION

The present invention is a system for inspecting a wafer, including inspecting both sides of a dual sided wafer or specimen. The wafer is mounted using a fixed three point mounting arrangement that holds the wafer at a relatively fixed position while simultaneously minimizing bending and stress. Light energy is transmitted through a lens arrangement employing lenses having diameter smaller than the specimen, such as half the size of the specimen, arranged to cause light energy to strike the surface of the wafer and subsequently pass through second collimating lens where detection and observation is performed.

The inventive system includes a variable coherence light source that transmits light energy through a collimator, which splits the light energy into two channels and directs the light energy

into two beams of light. The two beams of light are then directed through a series of lenses and mirrors to form two first order beams. Two of these first order beams are then directed to the

surface, while the other two are directed toward flat reflective surfaces facing the wafer surfaces. Another diffraction grating is positioned to receive the four first order beams and combine said beams into two separate channels, each of which are directed to a separate camera. Each camera is specially designed to receive the signal provided and resolve the image of the wafer surface.

In an alternate arrangement, the system includes at least one light source mounted proximate and substantially parallel to a flat in the arrangement previously described. The purpose of this optional source is to provide a catadioptric inspection of the surface. The light source, such as a helium-neon laser, passes through a beamsplitter, through a collimator, through the flat and strikes the wafer surface. The light beam then reflects off the wafer surface, passes through the flat, through the collimator, is deflected by the beamsplitter, and is received by a camera element or other sensing device.

The system optionally employs a calibration object for distortion calibration needed to match the front side and back side images of the wafer to determine the thickness variation of the wafer.

The system preferably includes at least one damping bar, where the number of damping bars depends on the wafer repositioning arrangement. The effect of

the damping bars is to provide a damping effect with VPI, or the Bernoulli principle. Each damping bar is positioned to provide a damping effect on the wafer.



to be damped. The proximity between any damping bar and the surface of the wafer is preferably less than .5 millimeters, and spacing of .25 and .33 may be successfully employed. Smaller gaps provide problems when warped specimens are inspected. One embodiment of the current invention employs a damping bar to cover slightly less than half of the specimen when in scanning position.

Mounting for the wafer uses a three point kinematic mount. The mounting points include clips having spherical or semi-spherical tangentially mounted contacts, mounted to a support plate and arranged to be substantially coplanar, where the clips are adjustable to provide for slight irregularities in the shape of the wafer. The adjustability of the contact points provide the ability to hold the wafer without a stiff or hard connection, which could cause bending or deformation, as well as without a loose or insecure connection, which could cause inaccurate measurements.

A wafer or specimen to be measured is held on a holding device such that both plane surfaces are arranged in vertical direction parallel to the light beam P. The wafer is supported substantially at its vertical edge so that both surfaces are not substantially contacted by the support post and are freely accessible to the interferometric measurement.

the wafer is supported in a vertical position by a support stand, which provides translation or sliding of the

arrangement. The system first performs an inspection of one portion of the specimen, and the translation stage and wafer are repositioned or translated such as by driving the translating stage so that another  
5 portion of the wafer is within the imaging path. The other portion of the wafer is then imaged, and both two sided images of the wafer are "stitched" together. Optionally, more than two scans may be performed and stitched together. The number of scans relates to the  
10 size of the wafer and the collimators and cameras used. Smaller components tend to be less costly, and thus while performing more than one scan may introduce stitching errors and require additional time to perform a scan of the entire surface, such a system  
15 may be significantly less expensive.

Other means for presenting the remaining portion of wafer or specimen may be employed, such as rotating the wafer mechanically or manually, or keeping the wafer fixed and moving the optics and imaging  
20 components. Alternately, scanning may be performed using multiple two-sided inspections of the module, such as three, four, or five or more scans of approximate thirds, quarters, or fifths, and so forth of the specimen. While multiple scans require  
25 additional time and thus suffer from increased throughput, such an implementation could provide for use of smaller optics, thereby saving overall system

each phase of the scan. It is actually preferred to

each scan to provide for a comparison between scans and the ability to "stitch" the two scans together.

Scanning and stitching involves determining the piston and tilt of the specimen during each scan, adjusting each scan for the piston and tilt of said scan, and possibly performing an additional stitching procedure. Additional stitching procedures include, but are not limited to, curve fitting the points between the overlapping portions of the two scans using a curve fitting process, replacing overlapping pixels with the average of both data sets, or weighting the averaging in the overlapping region to remove edge transitions by using a trapezoidal function, half cosine function, or other similar mathematical function. Background references are preferably subtracted to improve the stitching result. If significant matching between the scans is unnecessary, such as in the case of investigating for relatively large defects, simply correcting for tilt and piston may provide an acceptable result. However, in most circumstances, some type of curve fitting or scan matching is preferred, if not entirely necessary.

These and other objects and advantages of the present invention will become apparent to those skilled in the art from the following detailed description of the invention and the accompanying drawings.

The present invention is directed to a system for inspecting a specimen using a Moeller system for inspecting both sides of a semi-circular wafer or a similar object.

specimen is oriented in a substantially "vertical" orientation;

FIG. 1B is a preferred embodiment of the current invention;

5 FIG. 1C illustrates a holding arrangement for use in the current invention, including a damping bar and dual sided lensing arrangement;

FIG. 1D is a conceptual illustration of the anamorphic imaging system used in the system disclosed  
10 herein;

FIG. 1E shows a single channel camera system setup employed in the current system, including the optical components between the specimen or wafer and the CCD;

15 FIG. 2 presents the operation of mounting points for the wafer or specimen;

FIG. 3 illustrates a measurement module for use in connection with translating the wafer and performing multiple scans in the presence of multiple  
20 damping bars;

FIG. 4A shows the first position of the wafer or specimen relative to a damping bar when a rotational scanning and stitching procedure is performed on approximately half the wafer surface;

25 FIG. 4B is the second position of the wafer or specimen relative to a damping bar when a rotational scanning and stitching procedure is performed on the

portion of the wafer surface adjacent to the first position when a translational scanning and stitching procedure is performed on the entire wafer surface;

FIG. 5B is the second position of the wafer or specimen relative to a damping bar arrangement when a translational scanning and stitching procedure is performed on the other approximately half of the wafer surface;

FIG. 6 represents an algorithm for performing the scanning and stitching according to the present invention;

FIG. 7 presents a conceptual schematic representation of the components and optics necessary to perform the inventive dual sided imaging of a semiconductor wafer; and

FIG. 8 is a top view of the components and optics showing the path of light energy.

# 15 DETAILED DESCRIPTION OF THE INVENTION

FIG. 1B illustrates the reduced coherence inspection device of the current invention. According to FIG. 1B, a variable coherence light source 151 is employed. The variable coherence light source 151 may be, for example, a helium-neon laser, but generally any type of variable coherence light providing sufficient illumination characteristics for the apparatus and method described herein is acceptable. The variable coherence light source transmits light energy to collimator or collimating lens 152, which directs the light to first diffraction grating 153. The collimator 152 divides the light energy into

two beams of light energy. One beam of light energy is directed toward the specimen being examined. As shown in FIG. 1B, the

energy is directed toward the specimen and a pair of flat reflecting surfaces 154 and 155, where the flat reflecting surfaces may have either opaque characteristics, such as a standard mirror surface, or be semi transparent, i.e. transparent through one side and 90% reflective on the other. The dotted lines representing the waveform illustrated in FIG. 1 represent the higher order, such as first order, components of the light energy passing through the diffraction grating 153. The use of a zero order blocking surface (not shown) may be included in the system to prevent passage of the zero order component of the light energy emanating from the diffraction grating 153. The blocking surface may be any type of opaque surface, such as a light absorbing surface, dimensioned to prevent passage of zero order light components and permit those higher order components illustrated in FIG. 1B to reflect in the manner illustrated. Alternatively, a diffraction grating optimized for zero intensity of its zero order can be employed, negating the need for mechanical screens.

Light energy from each of the two channels strikes the specimen 111 and each channel further reflects off a respective flat 154 or 155. Light is thereby deflected toward the second diffraction grating 156, which combines the reflected energy received from the flat 154 or 155 and the specimen

each channel. The light is then directed through a collimator to a camera. Collimators 157 and 158

decollimate the light energy received from the second diffraction grating 156.

In the system illustrated in FIG. 1B, reference surfaces and specimen surfaces are positioned such that the reference wave fronts and specimen wave fronts travel the same path length. Phase shifting may be established by moving the reference surfaces, the diffraction gratings, or the light source. Thus the overall effect of the system illustrated in FIG. 1B is to decrease the spatial coherence between the reference wave fronts and the specimen wave fronts.

As shown in FIG. 1B, an optional interferometric normal incidence inspection device may be employed in the system described above, including a light emitting device, such as a laser 171, a beam splitter 172, and a collimator 173. The flat 155 serves as a reference surface. Light emitted from the light emitting device passes through the beam splitter toward the collimator, which collimates the light beam and passes it through the, in this case, semi transparent, flat 155 and toward the specimen 111. Light then reflects from the surface of the specimen 111 and from the reflective surface of the flat 155 facing the specimen, through the flat 155, through the collimator 173, and toward the beam splitter 172. The beam splitter 172 directs the reflected beam to supplemental collimator 174 and to a camera

with the illustrated two channels of information to provide additional information enhancing the quality

arrangement may also be employed on the other side of specimen 111, providing yet further optical information of the specimen surface.

The camera system 159 comprises camera arrangement 159A and camera arrangement 159B. The camera system or anamorphic imaging system has an aspect ratio of on the order of 2:1. In essence, the wafer in the configuration illustrated optically appears as a tilted object, and in the arrangement shown has an elliptical projection ratio of approximately 6:1. The camera system used should preferably resolve this elliptical projection ratio into an image having an aspect ratio closer to 1:1. Maintaining the aspect ratio of 6:1 can prevent detection of relatively significant magnitude.

The overall configuration of the anamorphic imaging system used in the system disclosed herein is shown in FIG. 1D. From FIG. 1D, the projection of the image has an elliptical aspect ratio of 6:1. The anamorphic imaging system 166 receives the elliptical image 167 and conveys the image to a viewing location, such as a CCD (Charged Coupled Device) such that the received image 168 has an aspect ratio of 2:1. This ratio provides the maximum utilization of a square image when imaging each of the wafer stitching regions. Different anamorphic imaging arrangements may be employed while still within the scope of the

arrangement of the present invention and the size and quality of defects expected, as well as the



A simplified drawing of the system from the wafer to the camera arrangement 153 is presented in FIG. 1E. FIG. 1E is not to scale and represents a single channel of inspection rather than a dual channel and dual camera arrangement. From FIG. 1E, wafer or specimen 111 reflects the light energy toward second diffraction grating 156, which passes light to collimator 173, comprising decollimating lenses 173A and 173B, and to a camera arrangement 159A. Camera arrangement 159A comprises seven imaging lenses used to resolve the 6:1 image received into a 2:1 image for transmission to CCD 160. Any lensing arrangement capable of producing this function is acceptable, and the camera arrangement 159A is therefore not limited to that illustrated in FIG. 1E.

An additional feature of the current system is the use of a calibration object for distortion calibration. In the system illustrated, a calibration object 175 (not shown) is used in place of wafer or specimen 111. The use of a calibration object provides a known reference which enables accurate matching of images on the front and back side of the wafer 111 with sub pixel accuracy. The use of the calibration object 175 permits calculation of the thickness variation of the specimen by determining the difference between the front and back topography maps of the specimen. The calibration object is similar to

the calibration object features are detected using the system/interferometer with pixel accuracy. One

of circular raised features having relatively small diameters/pitches, such as on the order of 5 to 10 millimeters, and covering both the front and back surfaces. Other patterns, pitches, and spacings may  
5 be employed as long as the precision of the measuring device may be determined.

In operation, the calibration object 175 is placed as shown in FIGs. 1B and 1C and images of the front surface and back surface obtained. The features  
10 on the front and back surfaces of the calibration object are measured and their locations are determined to within the desired accuracy. A spatial transformation is computed which maps the measured locations of the features to their actual locations.  
15 The wafer or specimen 111 is positioned in the system as shown, with sufficient care taken to place the wafer or specimen 111 in an identical position to the calibration object 175. The specimen is then examined on both front and back sides and the thickness  
20 variation determined by applying the same spatial transformation as for the calibration wafer

FIG. 1C illustrates scanning both sides of a dual-sided wafer or specimen 111. According to FIG. 1C, the wafer 111 is mounted using a fixed three point  
25 mounting arrangement as shown in FIG. 2. The three point mounting arrangement serves to hold the wafer 111 at a relatively fixed position while

the scanning beam 113 is directed at the light energy to strike the surface of the wafer 111

113 where detection and observation is performed. As may be appreciated by examining FIG. 1C, the diameter of both first collimating lens 112 and second collimating lens 113 are significantly smaller than the diameter of the specimen or wafer 111, and incident light strikes only a portion of the surface of wafer 111. Not shown in the illustration of FIG. 1C is that while light energy is striking the surface of wafer 111 visible in the arrangement shown, light energy simultaneously passes through first collimating lens 112 and strikes the reverse side of the wafer 111, not shown in FIG. 1C. Light energy passes from the reverse side of the specimen 111 through second collimating lens 113.

15 The arrangement further includes an upper damping bar 114 and a lower damping bar 115. In the arrangement shown in FIG. 1C, the upper damping bar 114 covers approximately one half of the specimen 111, specifically the half not being inspected. The effect of the damping bar is to damp the non-measured surface of the specimen 111 to minimize the effects of vibration. Damping in this arrangement is based on VED, or the Bernoulli principle, wherein the upper damping bar 114 in the arrangement shown is brought to 20 within close proximity of the surface to be damped. The proximity between either damping bar 114 or 115 and the surface of the wafer is preferably less than

25 providing smaller gap between either damping bar 114 or 115 and the surface of wafer 111 is that any

surface. For this reason, and depending on the wafer surface, gaps less than .10 millimeters are generally undesirable. Further, gaps greater than 1.0 millimeters do not produce a desirable damping effect, as the Bernoulli principle does not result in sufficient damping in the presence of gaps in excess of 1.0 millimeter.

The gap between the specimen 111 and upper damping bar 114 or lower damping bar 115 restricts airflow between the specimen and the damping bar and damps vibration induced in the specimen. Each damping bar is generally constructed of a stiff and heavy material, such as a solid steel member. Overall dimensions are important but not critical in that the damping bar should cover a not insignificant portion of the wafer 111. Coverage of less than 20 per cent of the wafer tends to minimize the overall damping effect on the wafer, but does provide some level of damping.

The illumination of only a portion of the wafer 111 permits use of smaller lenses than previously known. In the embodiment shown in FIG. 1B, the preferred size of the first collimating lens 112 and second collimating lens 113 is approximately 4.4 inches where the wafer 111 is 300 millimeters in diameter. In such an arrangement, the damping bars 114 and 115 are approximately 4.5 inches wide. Length

of the damping bars is not critical.

As shown in FIG. 1, the mounting for the wafer 111 is preferably using a three point kinematic mount,

spherical or semispherical contacts tangential to one another. Points 201, 202, and 203 are small clips having spherical or semi-spherical tangentially mounted contacts, mounted to a support plate such as mounting plate 116 to be substantially coplanar, with adjustable clips to provide for slight irregularities in the shape of the wafer 111. The spherical or semispherical components should be sufficiently rigid but not excessively so, and a preferred material for these components is ruby. The adjustability of points 201, 202, and 203 provide an ability to hold the wafer 111 without a stiff or hard connection, which could cause bending or deformation, as well as without a loose or insecure connection, which could cause inaccurate measurements. In FIG. 1C, two lower kinematic mount points 202 and 203 (not shown) support the lower portion of the wafer 111, while the upper portion is supported by mount point and clip 201. The points 201, 202 and 203 are therefore stiff enough to mount the wafer or specimen 111 and prevent "rattling" but not so stiff as to distort the wafer. The spherical or semispherical contact points are generally known to those of skill in the mechanical arts, particularly those familiar with mounting and retaining semiconductor wafers. The combination of clamping in this manner with the Bernoulli damping performed by the damping bars 114 and 115 serves to

specimen is generally performed in accordance with IOT Application PCT/EP/84-81 to Dieter Mueller, currently

of the current application. The entirety of PCT/EP/03881 is incorporated herein by reference. This imaging arrangement is illustrated in FIGS. 7 and 8, and is employed in conjunction with the arrangement 5 illustrated and described with respect to FIG. 1B herein. FIGS. 7 and 8, as well as FIG. 1B, are not to scale. As shown in FIGS. 7 and 8, the light energy directing apparatus employed in the current invention comprises a light source in the form of a laser 801. 10 The light emitted from the laser 801 is conducted through a beam waveguide 802. The light produced by the laser 801 emerges at an end 803 of the beam waveguides 802 so that the end 803 acts as a punctual light source. The emerging light strikes a deviation 15 mirror 804 wherefrom it is redirected onto a collimation mirror 807 in the form of a parabolic mirror by two further deviation mirrors 805 and 806. Deviation mirrors 805 and 806 are oriented at an angle of  $90^\circ$  relative to each other. The parallel light beam 20 P reflected from the parabolic mirror 807 reaches a beam splitter 808 through the two deviation mirrors 805 and 806.

The beam splitter 808 is formed as a first diffraction grating. The beam splitter 808 is 25 arranged in the apparatus in a vertical direction and the parallel light beam P strikes the diffraction grating in a perpendicular direction. A beam splitter 809 is arranged behind the beam splitter 808 and parallel thereto. Behind the beam splitter 809 two decollimation lenses 811 are arranged at equal

level and the light beams leaving these decollimation lenses are each deflected and focused onto two CCD cameras 816A and 816B, through deviation mirror pairs 812A and 812B, 813A and 813B, and 814A and 814B, and to an optical imaging system 15.

The beam splitter 808 is supported transversely to the optical axis and further comprises a piezoelectric actuating element 817 for shifting the phase of the parallel light beam P by displacing the diffraction grating.

A holding device 830, for example the holding device disclosed herein and described with respect to FIGs. 1C, 2, and 3, is provided between the first diffraction grating and the second diffraction grating. Other holding devices may be employed while still within the scope of this invention, such as a support post. A wafer or specimen 809 to be measured is held on the holding device 830 such that both plane surfaces 831 and 832 are arranged in vertical direction parallel to the light beam P. The wafer 809 is supported by the support post substantially at its vertical edge 833 only so that both surfaces 831 and 832 are not substantially contacted by the support post and are freely accessible to the interferometric measurement.

Moreover, an optional receiving device (830, 825) may be provided for measuring the wafer 809. This

the wafer 809 is shown in FIG. 1, 2, and 4. The wafer can be inserted into the receiving

tilting device 826 the wafer 809 may be tilted from its horizontal position into the vertical measuring position, and the wafer 809 may be transferred, by means of a positionable traveller, into the light path  
5 between the first diffraction grating and the second diffraction grating so that the surfaces 809 and 831 to be measured are aligned substantially parallel to the undiffracted light beam P and in a substantially vertical direction.

10 Furthermore, a reference apparatus 820 may be provided which comprises a reference body 821 having at least one plane surface 824. The reference body 821 can be introduced into the light path between the first diffraction grating 808 and the second  
15 diffraction grating 810 in place of the semiconductor wafer or specimen 809 to be measured by means of a traveller 823 with a linear guide 818. The reference body 821 is held so that its plane surface 824 is arranged in vertical direction parallel to the  
20 undiffracted light beam P. The reference body 821 can be turned by 180° in its mounting around an axis parallel to its surface 824.

In operation the wafer or specimen 809 to be measured is first inserted into the wafer receiving  
25 device 825. The surfaces 831 and 832 are horizontally arranged. By means of the tilting device and of the traveller 819 the wafer to be measured is brought into

the position in which the surfaces 831 and 832 are aligned parallel to the parallel light beam P striking the first diffraction grating 808 at the beam splitter region.



partial light beams A, B, whereby the first order component of the partial light beam A having a positive diffraction angle strikes the one surface 831 of the wafer 809 and is reflected thereat. The first  
5 order component of partial light beam B with a negative diffraction angle strikes the other surface 832 of the wafer and is reflected thereat. The first order component of partial light beams A and B each strike the respective flat, or mirrored surface, where  
10 the first order component of partial light beam A strikes flat 851, and first order component of partial light beam B strikes flat 852. The 0-th diffraction order of the parallel light beam P passes through the first diffraction grating 808 and is not reflected at  
15 the surfaces 831 and 832 of the wafer 809. This partial light beam P serves as reference beam for interference with the reflected wave fronts of the beams A and B. Each 0-th order beam is preferably blocked by blocking surfaces 853 and 854. In the  
20 second diffraction grating 810, the beam collector and the reflected first order components of partial light beams A and B are each combined again with the reference beam P and focused, in the form of two partial light beams A + P and B + P onto the focal  
25 planes of the CCD cameras 816A and 816E through decollimation lenses 811 and deviation mirrors 812, 813 and 814 as well as positive lenses 815.

...  
multiplied by  $\pi^\circ$  and  $12^\circ$  by displacing the diffraction gratings. This produces phase shifted interference

patterns. The defined shift of the interference phase produced by the phase shifter 817 is evaluated to determine whether there is a protuberance or a depression in the measured surfaces 831 and 832 the  
5 two digitized phase patterns are subtracted from each other.

A calibration using the reference body 821 may optionally be performed before each measurement of a wafer 809. The reference body 821 is introduced into  
10 the beam path between the first diffraction grating 808 and the second diffraction grating 810. The known plane surface 824 is measured. Subsequently the reference body 821 is turned by 180° and the same surface 824 is measured as a second surface.

15 FIG. 3 illustrates the measurement model without a wafer or specimen present. From FIG. 3, light source 301 initially emits light energy and is focused to strike first mirror surface 302 and second mirror surface 303 (not shown). Each of these two mirror  
20 surfaces direct light energy through first collimating lens 112 (not shown in this view) and light energy strikes the two surfaces of specimen 111 (also not shown) simultaneously. After striking the two surfaces of specimen 111, light energy is directed  
25 through second collimating lens 113 (also not shown in FIG. 2) and to third mirror 304 and fourth mirror 305, which direct light energy toward focusing element 206

and the like. The focusing element 206 may be a lens or a lens element or a combination of lens elements and lens elements known in the art, and may include a lensing

arrangement, such as multiple lenses, and a CCD or other imaging sensor. Other implementations of focusing element 306 and detector or sensor 307 are possible while still within the scope of the current invention.

From FIG. 1C, the specimen 111 is mounted to three points, including point 201, which are fixedly mounted to mounting surface 116. Mounting surface 116 may be fixedly mounted to translation surface 117. Either translation surface 117 or mounting surface 116 is fastened to translation stage 308, which provides translation or sliding of the mounting surface 116 and specimen 111 within and into the arrangement shown in FIG. 3. The arrangement may further include translation surface 117 depending on the application. Translation stage 308 permits the arrangement of FIG. 1B, specifically wafer or specimen 111, points 201, 202, and 203, mounting surface 116, and translation surface 117, to move up and down in a relatively limited range, as described below. In such an arrangement employing translation surface 117, the translation surface and the mounting surface along with the contact points are positioned within the measurement module 300, preferably by affixing the translation surface 117 to the translation stage 308. Specimen 111 is then physically located between damping bars 114 and 115, as well as proximate damping

bars 114 and 115, and inspection of the lower portion of the wafer is initiated. After completing

portion of the specimen 111 with acceptable results, the translation stage 308 and ultimately the wafer are repositioned or translated such as by driving the translating stage 308 along track 310 such that  
5 another portion of the wafer 111, such as the remaining approximately half of specimen 111 is within the imaging path. The other portion of the wafer is then imaged, and both of the two sided images of the wafer surface are "stitched" together.

10 The damping bars may have varying size while still within the scope of the current invention, as discussed above. In FIG. 3, the damping bars are affixed to end pieces 310 and 311, but any type of mounting will suffice as long as the gap spacing  
15 described above and the ability to perform scans on desired portions of the wafer is available.

As may be appreciated, other means for presenting the remaining portion of wafer or specimen 111 may be employed, such as rotating the wafer by hand by  
20 releasing contact with the points and rotating the wafer manually. Alternately, a mechanical rotation of the specimen may occur, such as by rotatably mounting the mounting surface 116 on the translating surface 117 while providing for two locking positions for the  
25 mounting surface 116. In other words, the arrangement of wafer 111, points 201, 202, and 203, and mounting surface 116 would initially fixedly engage translation

surface 117, and mounting surface 116 would be unlocked from translation surface 117 and be

perpendicular to translation surface 117. The wafer and associated hardware rotate 180 degrees to a second locking position, wherein the surface would lock and a second inspection scan would commence. During this rotation scheme, damping bars and impediments would be mechanically or manually removed to prevent contact with mounting points 201, 202, and 203. The various components, particularly mounting surface 116, are sized to accommodate rotation within the measurement module 300 without contacting the translation stage or other module components.

Alternately, scanning may be performed using multiple two-sided inspections of the module, such as three, four, or five scans of approximate thirds, quarters, or fifths of the specimen. While multiple scans require additional time and thus suffer from increased throughput, such an implementation could provide for use of smaller optics, thereby saving on system costs. Numerous sub-aperture scans may be performed by a system similar to that illustrated in FIG. 3 while still within the scope of the current invention.

FIGS. 4A and 4B illustrate a rotational scanning arrangement of the wafer or specimen 111. As may be appreciated, in a two phase scan of a dual sided specimen, at least 50 per cent of the surface must be scanned in each phase of the scan. It is actually

between scans and the ability to "link" the two scans together. In such an arrangement, as shown in

initially, shown as portion A of the surface 111. Portion B is obscured by one of the damping bars. After the initial scan phase, the specimen 111 is rotated manually or mechanically to the position illustrated in FIG. 4B. Approximately 55 per cent of the wafer surface, both front and back, are scanned during this second phase. This provides an overlap of five per cent of the wafer, and comparisons between these overlap portions provides a reference for stitching the scans together. In FIG. 4B, the A portion of the wafer is obscured by the damping bar.

Alternately, as in the arrangement shown in FIG. 3, the wafer or specimen 111 may be translated vertically and two or more separate scans performed. As shown in FIGS. 5A and 5B, a portion of the wafer 111 is positioned between two damping bars, such as damping bars 114 and 115, and the portion marked "B" in FIG. 5A is scanned. As shown therein, greater than 50 per cent of the specimen 111 is scanned so that the overlapping portion may be stitched with the second scan. After the initial scan, the wafer is translated to a position as shown in FIG. 5B. Portion "A" of FIG. 5B is then scanned, while the lower damping bar covers much of section "B." The overlapping portions of the two scans are then stitched together to provide a full representation of the surface, and again such a scan is dual-sided.

specimen 111 is rotated as shown in FIGs. 4A and 4B, while two damping bars are required in the wafer

Note that due to measurement setup, an arbitrary piston or DC offset and tilt will be applied to each of the measurements, indicating that some correction is required prior to or during stitching to obtain an accurate surface representation.

FIG. 6 illustrates a general scanning and stitching algorithm for use in accordance with the invention described herein. The algorithm begins in step 601 and performs the first scan in step 602, as well as determining the piston and tilt of the specimen 111. The algorithm evaluates whether the scan is acceptable in step 603, either performed by an operator actually evaluating the scan or a mechanical comparison with a known or previous scan. If the scan is acceptable, the algorithm proceeds to step 604 where the wafer is repositioned to the next location. If the scan is not acceptable, the wafer is rescanned in its original position. Piston and tilt may be recomputed, but as the wafer has not moved this is not necessary. Once the wafer has been repositioned in step 604, a subsequent scan is performed in step 605 and the tilt and piston computed for the new orientation. The acceptability of the scan is evaluated in step 606, and if unacceptable, the scan is performed again. The piston and tilt again do not need to be recalculated. Once the scan is mechanically or visually deemed acceptable, the algorithm proceeds to step 607. If the scan is deemed acceptable, the wafer is again repositioned and the remaining scans performed in accordance with the algorithm.

scanned, the algorithm sets x equal to one and y equal to 2 in step 608. In step 609 the system alters scan x for tilt and piston and separately alters scan y for its respective tilt and piston. At this point scans x and y are neutrally positioned and may be stitched together. Step 610 is an optional step of performing an additional stitching procedure. Additional stitching procedures include, but are not limited to, curve fitting the points between the overlapping portions of the two scans using a curve fitting process, replacing overlapping pixels with the average of both data sets, or weighting the averaging in the overlapping region to remove edge transitions by using a trapezoidal function, half cosine function, or other similar mathematical function. Background references are preferably subtracted to improve the stitching result. If significant matching between the scans is unnecessary, such as in the case of investigating for relatively large defects, simply correcting for tilt and piston may provide an acceptable result, and step 610 need not be performed. However, in most circumstances, some type of curve fitting or scan matching is necessary. Scans are matched and stitched in step 611. Such stitching algorithms should preferably be performed using a computing device, such as a microprocessor (not shown).

Step 612 evaluates whether the complete wafer has

been scanned. If not, the system returns to step 608. If the complete wafer has been scanned, the algorithm



Based on the disclosure presented above and in particular in connection with that shown in FIG. 3, the wafer 111 is generally repositioned while the inspection energy source and optics remain fixed.

- 5 While this implementation provides distinct advantages in setup time for performing multiple dual-sided wafer scans, it is to be understood that the light source and associated optics and detector may be slidably or rotationally mounted while the wafer remains fixed.
- 10 In the configuration illustrated in FIG. 3, source 301, support elements 310 and 311, damping bars 114 and 115, damping bar 309, the four mirrors 302, 303, 304, and 305, focusing element 306, and detector 307 may be mounted to a single surface and fixedly
- 15 positioned relative to one another, and translated or rotated about the wafer. Alternately, the components may be translated either together or individually to perform subsequent scans of the wafer or specimen 111.

While the invention has been described in

20 connection with specific embodiments thereof, it will be understood that the invention is capable of further modifications. This application is intended to cover any variations, uses or adaptations of the invention following, in general, the principles of the

25 invention, and including such departures from the present disclosure as come within known and customary practice within the art to which the invention